Status of Layer 0 and Analog Cable for D0 run2b silicon tracker

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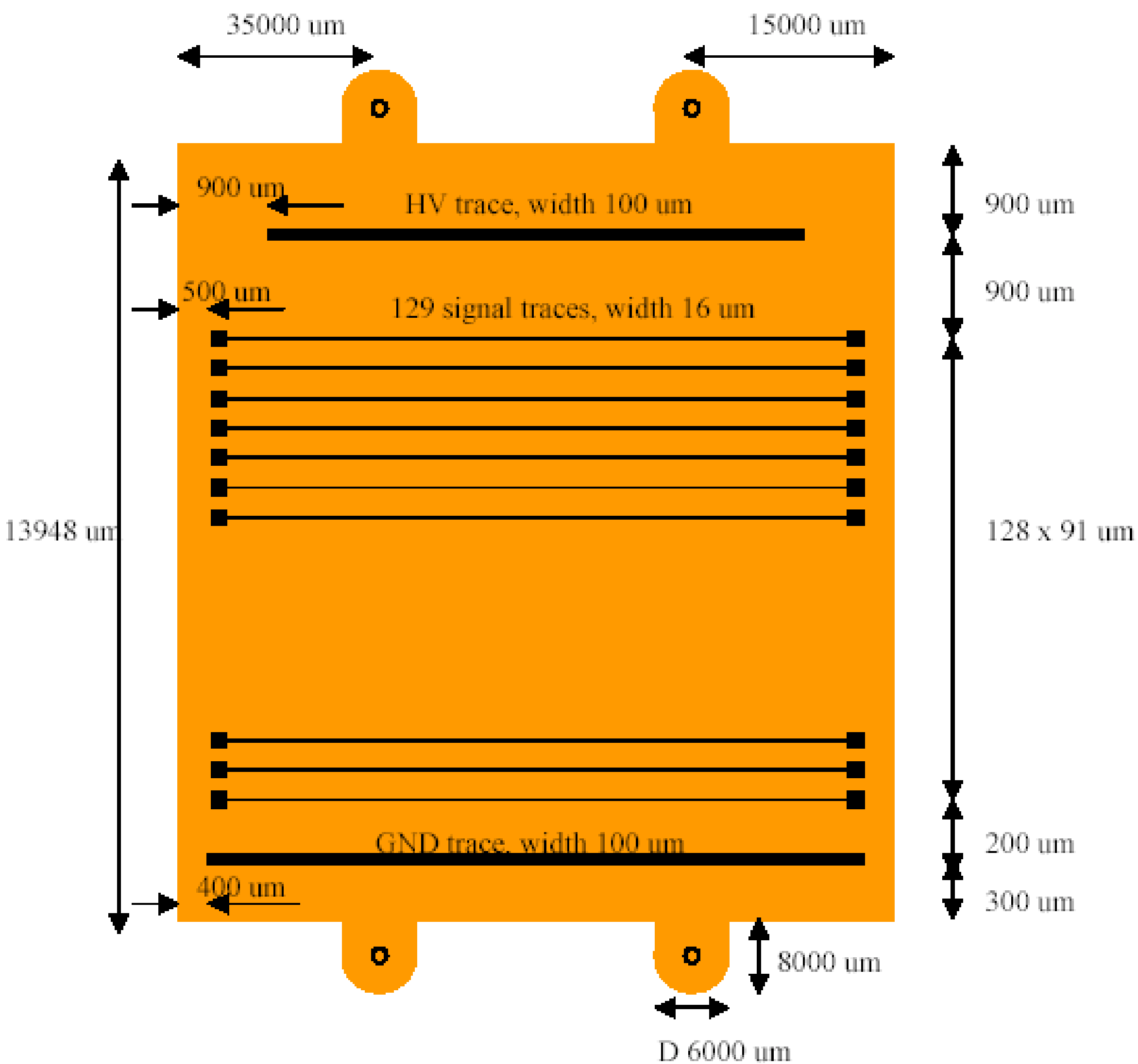
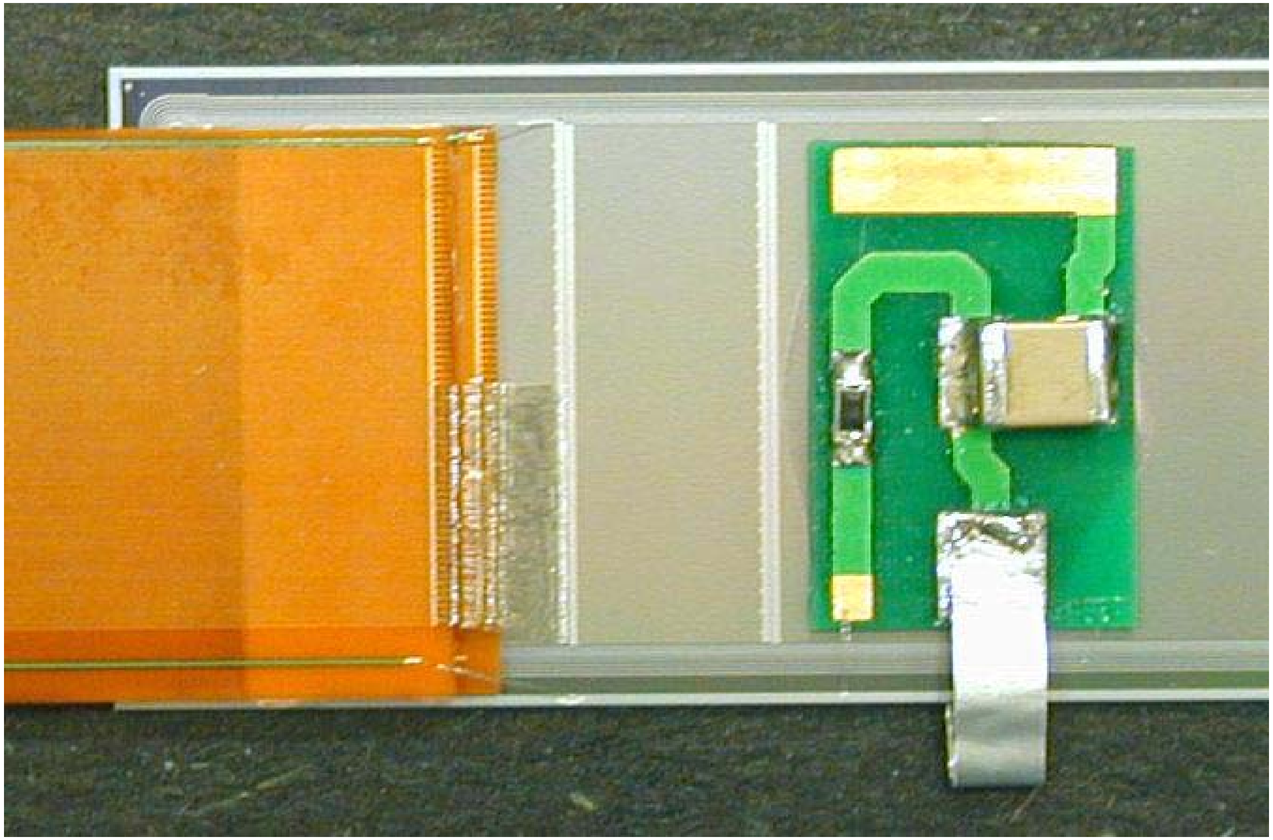
- Analog cable design.
- Prototype analog cable.
- Proximity of analog cable to grounding/shielding.
- Grounding/Shielding studies with L0 prototype.
- Summary

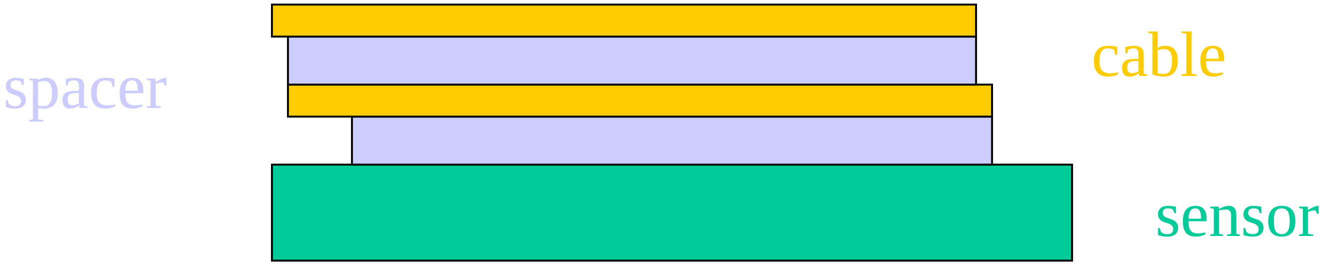
Cable design



- 91µm trace pitch
- 16µm trace width
- Two cables work as a pair for one sensor.
- Kapton type polyimide substrate plus copper traces.
- The longest 464mm.
- The shortest 271mm.

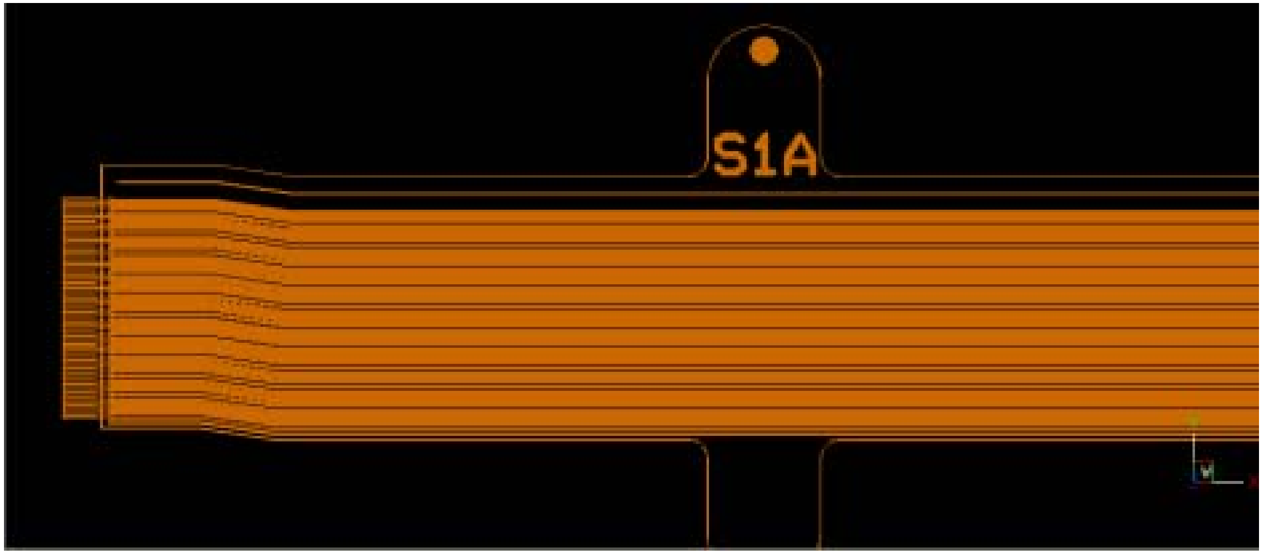
Cable design (cont'd)





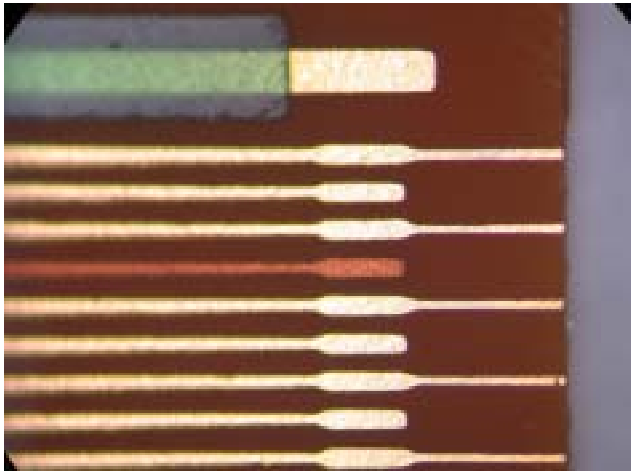
Cable design (cont'd)

- A "jog" at sensor side, where traces are shifted vertically by ~0.6 mm over a length of a few mm.



Prototype cables by Dyconex (3rd and 4th prototype)

- all cables are Ni-Au plated (~1.2μm) over the full length, solder mask only on HV+GND traces
- visual inspection on cables:
  - look for not gold-plated (copper) pads.



4th prototype

3rd prototype

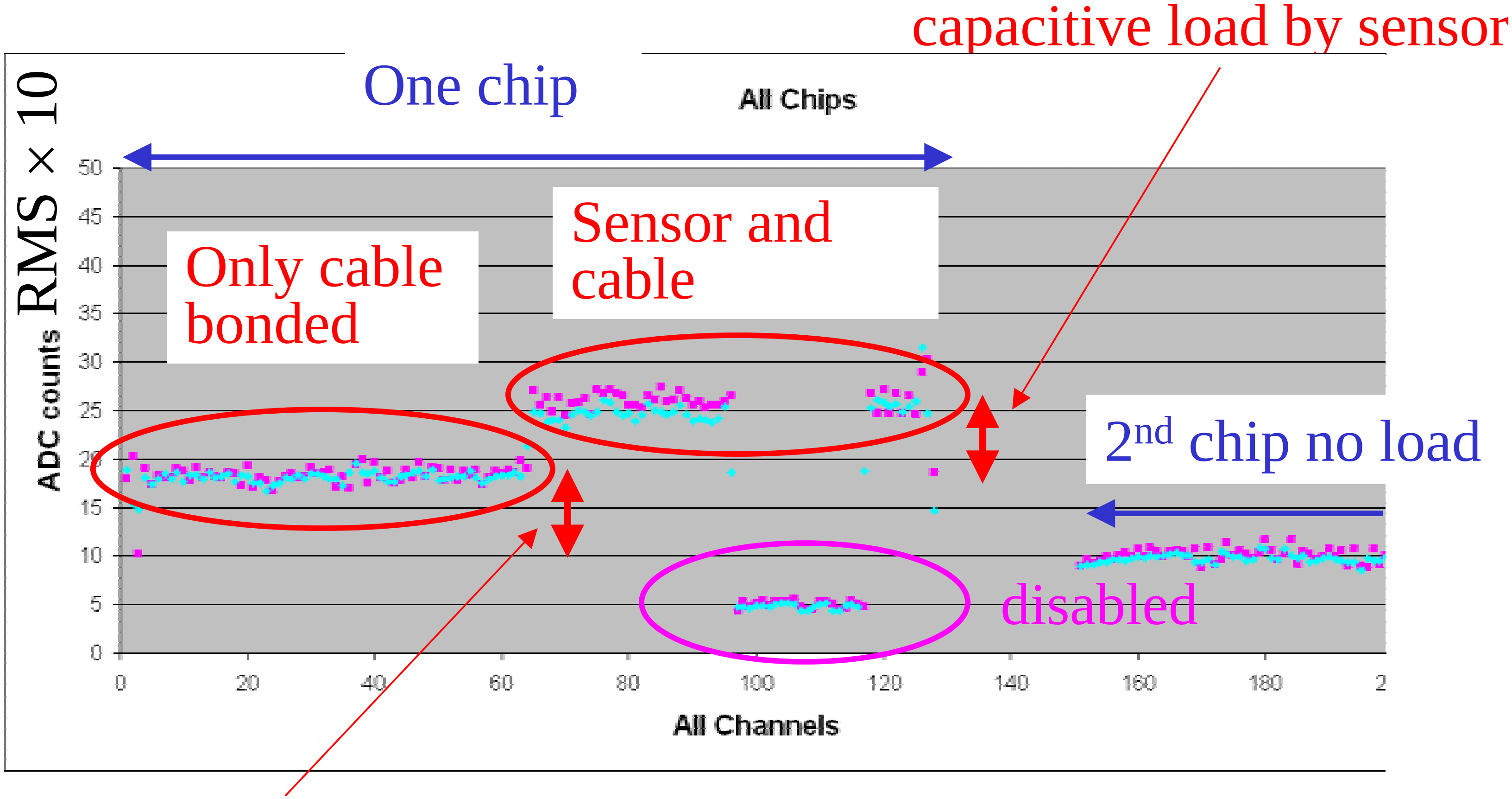
# open traces	0	1	2	>2
#cables	22	13	4	0

No single opens out of 40 cables.

  - 129 traces→one open is allowed.
  - trace width on cables: 9-12μm for 3rd and ~19μm for 4th prototypes.

Capacitance (one to neighbors) ~ 0.35pF/cm measured by LCR meter.

Noise due to capacitance

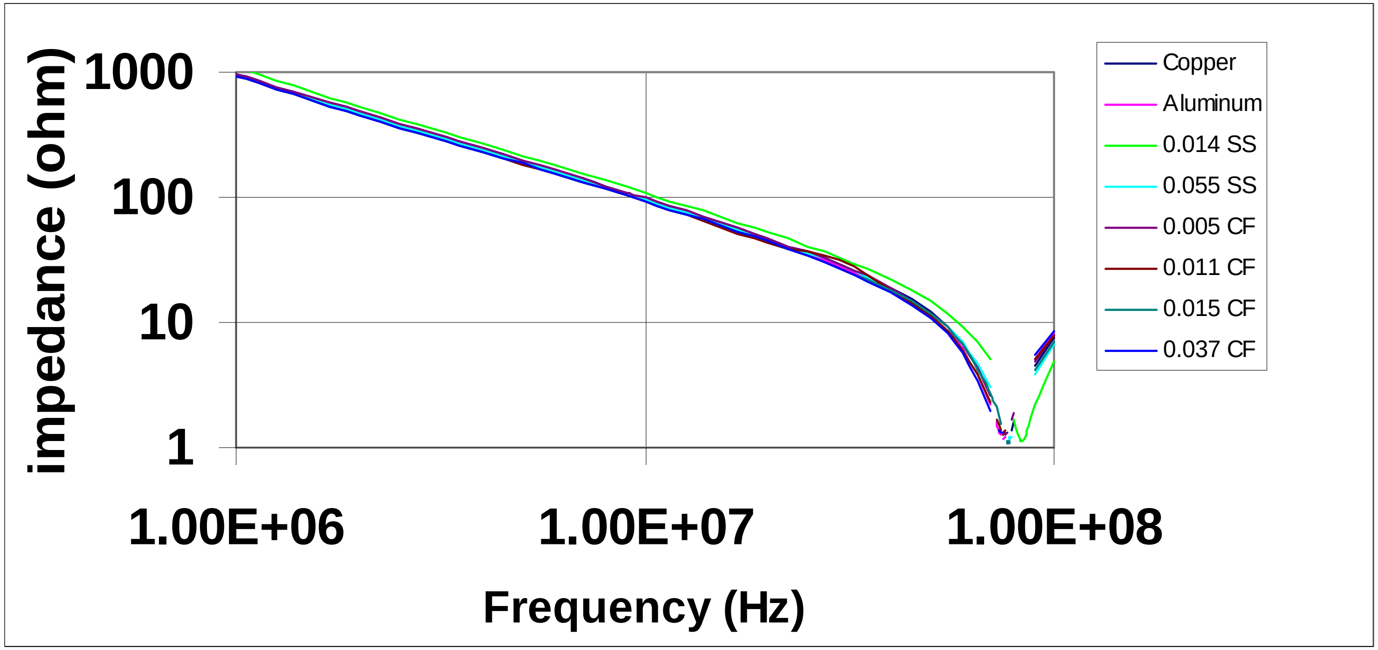


capacitive load by cable (0.8ADC~600e)

SVX4 ENC: const+41C ➔ 600e indicates C = 15pF

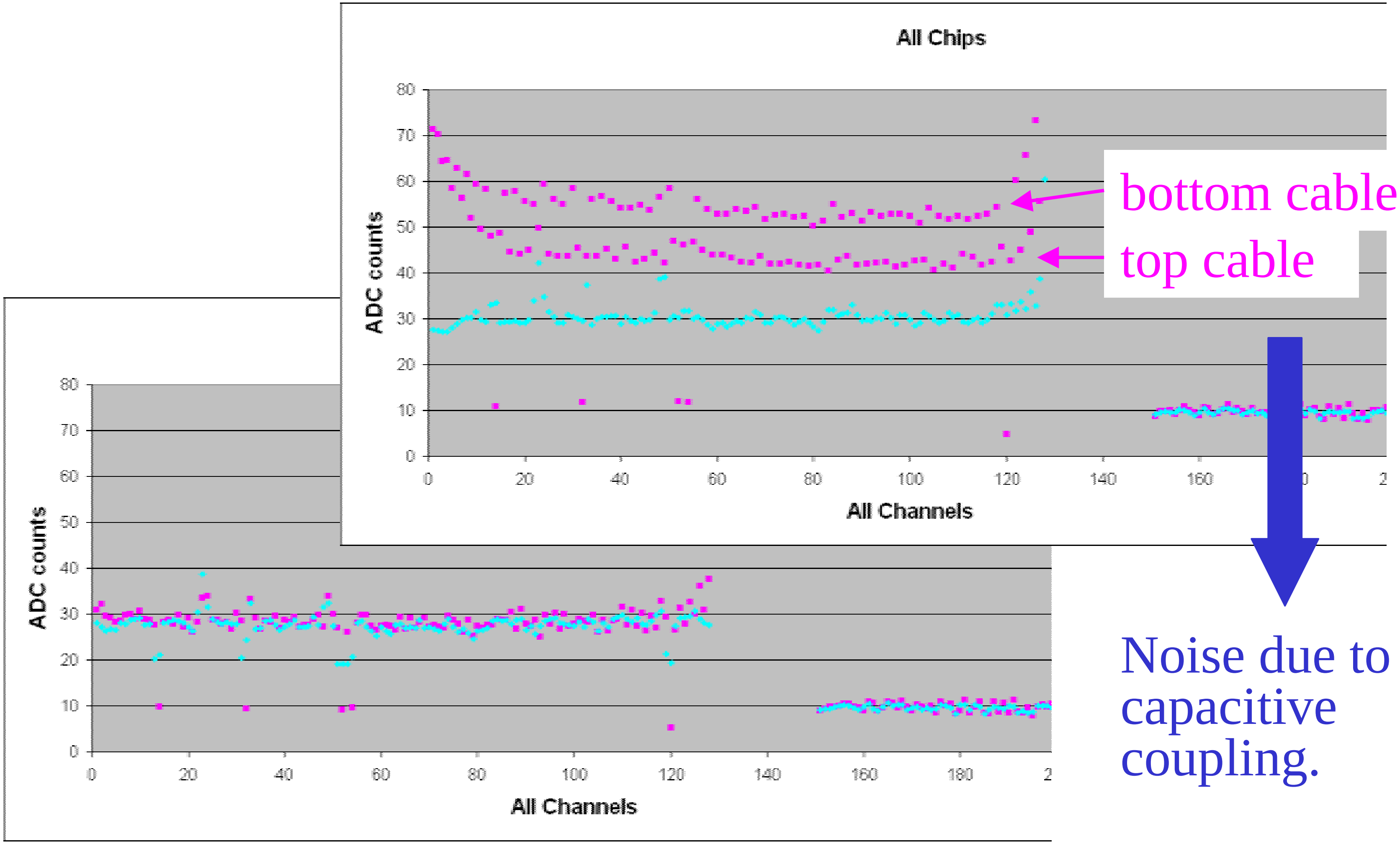
Proximity to grounding plane

- Either additional shielding or Carbon Fiber structure works as grounding plane.



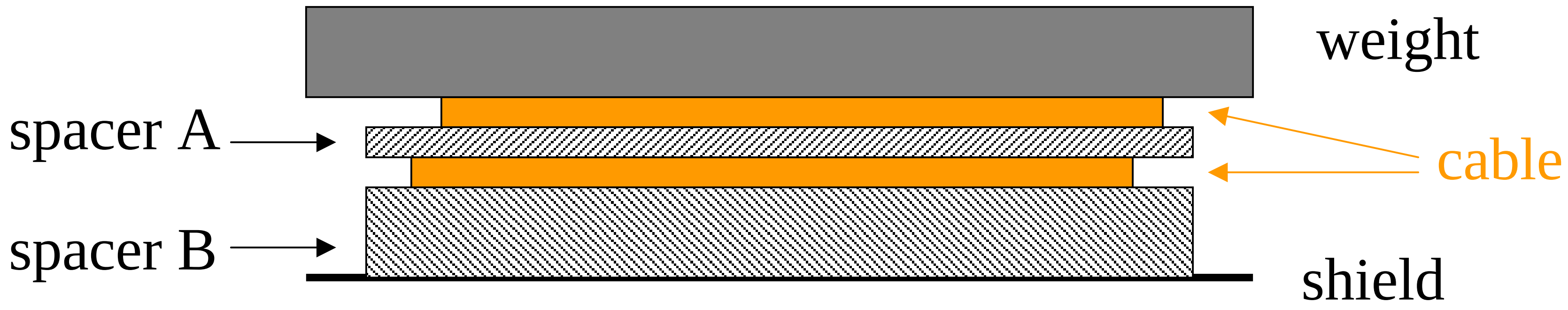
- Proximity to the grounding plane is an issue.

Proximity to the grounding/shielding



- Only the difference is the weight on top of the cables.
  ➔ Proximity to the shielding material.

Proximity to the Shielding (cont'd)



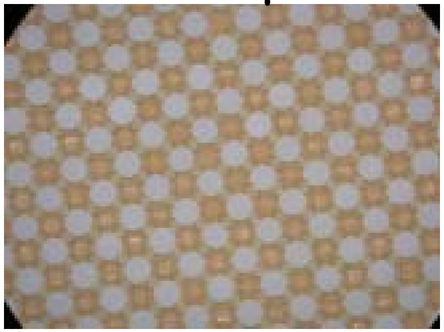
A:nothing B:	top	bottom
75µm Kapton (no weight)	2.8	2.8
75µm Kapton + 400µm polypropylene mesh	2.8	2.9
75µm Kapton + 200µm polypropylene mesh	3.2	3.3
75µm Kapton	4.3	5.3

- The study is still on going…

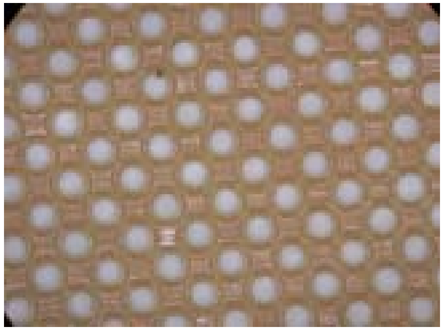
Choice of spacer

- Dyconex has produced three different meshes with kapton sheet.
  - hole radius: 60 μm
  - hole-distance: 190, 210 and 230 μm
  - corresponding to ε_r ~1.95, 2.2 and 2.45

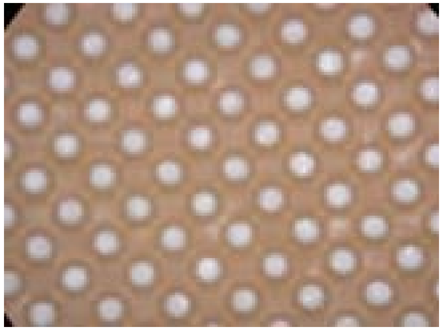
190 μm



210 μm

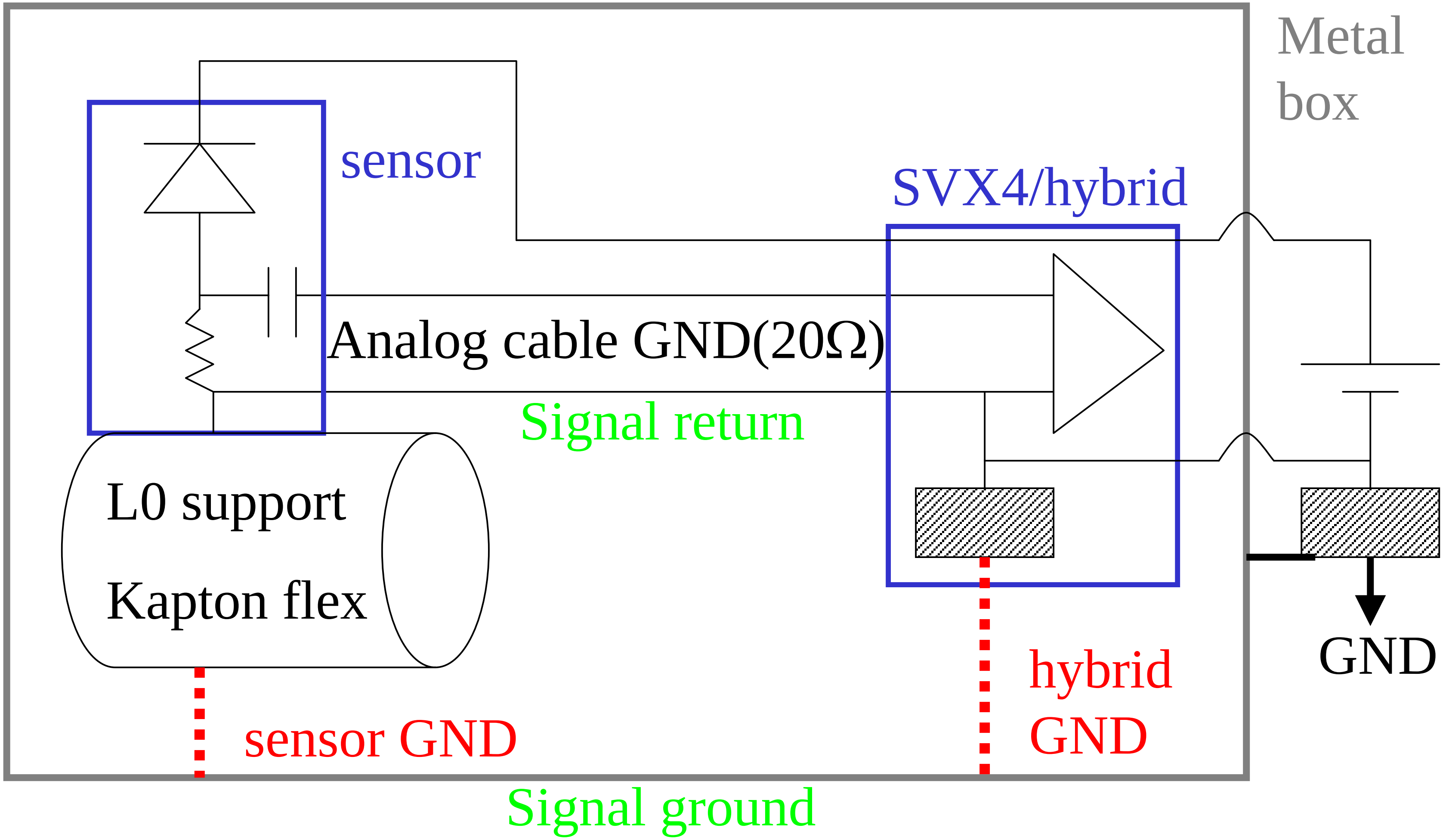


230 μm

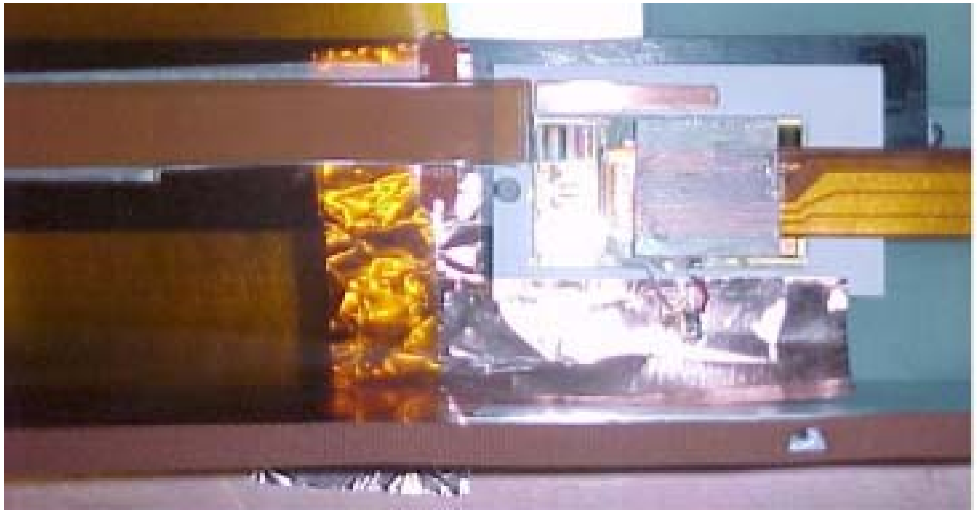


- Polypropylene mesh sheet

Grounding Studies

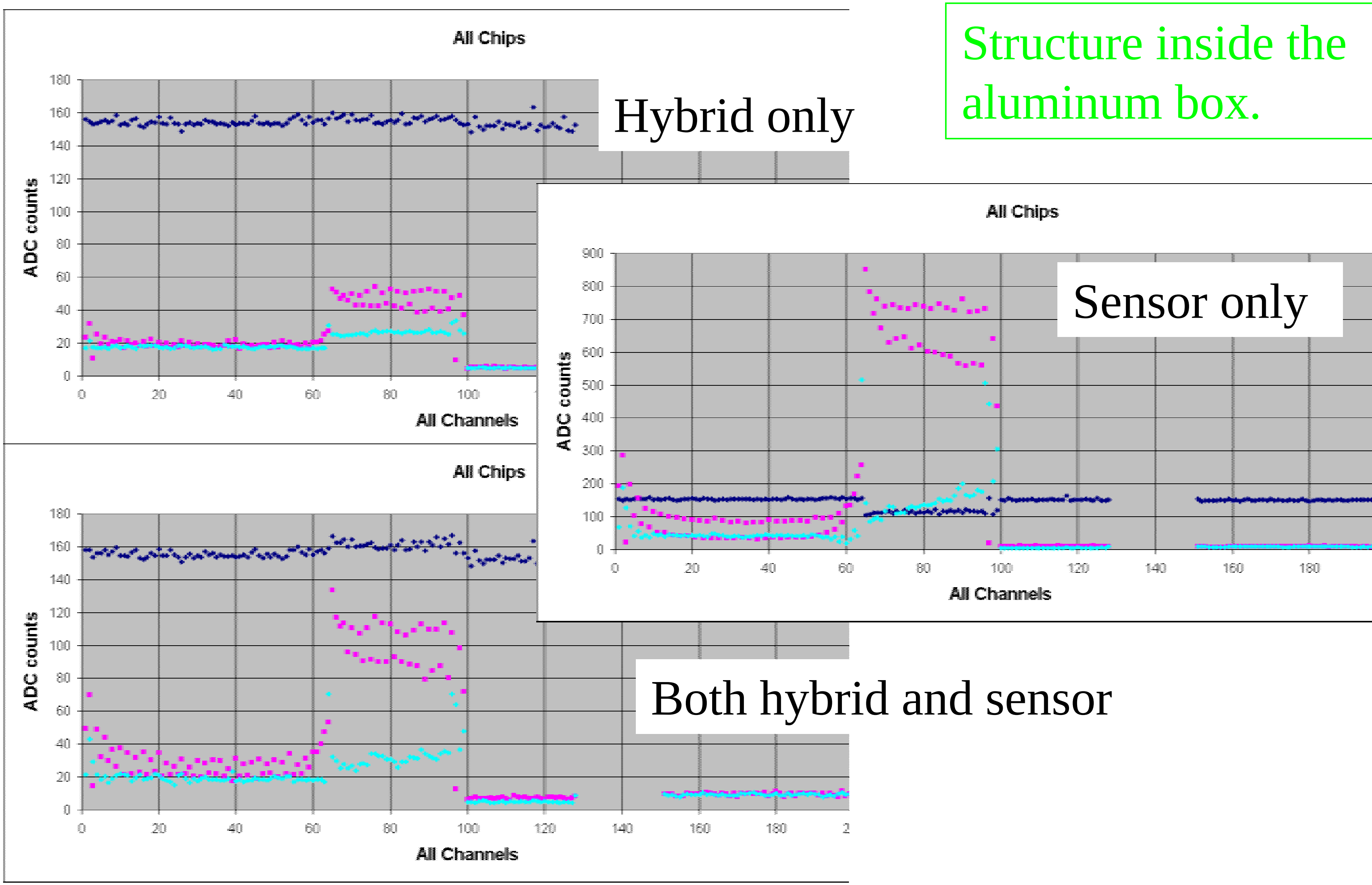


L0 prototype module

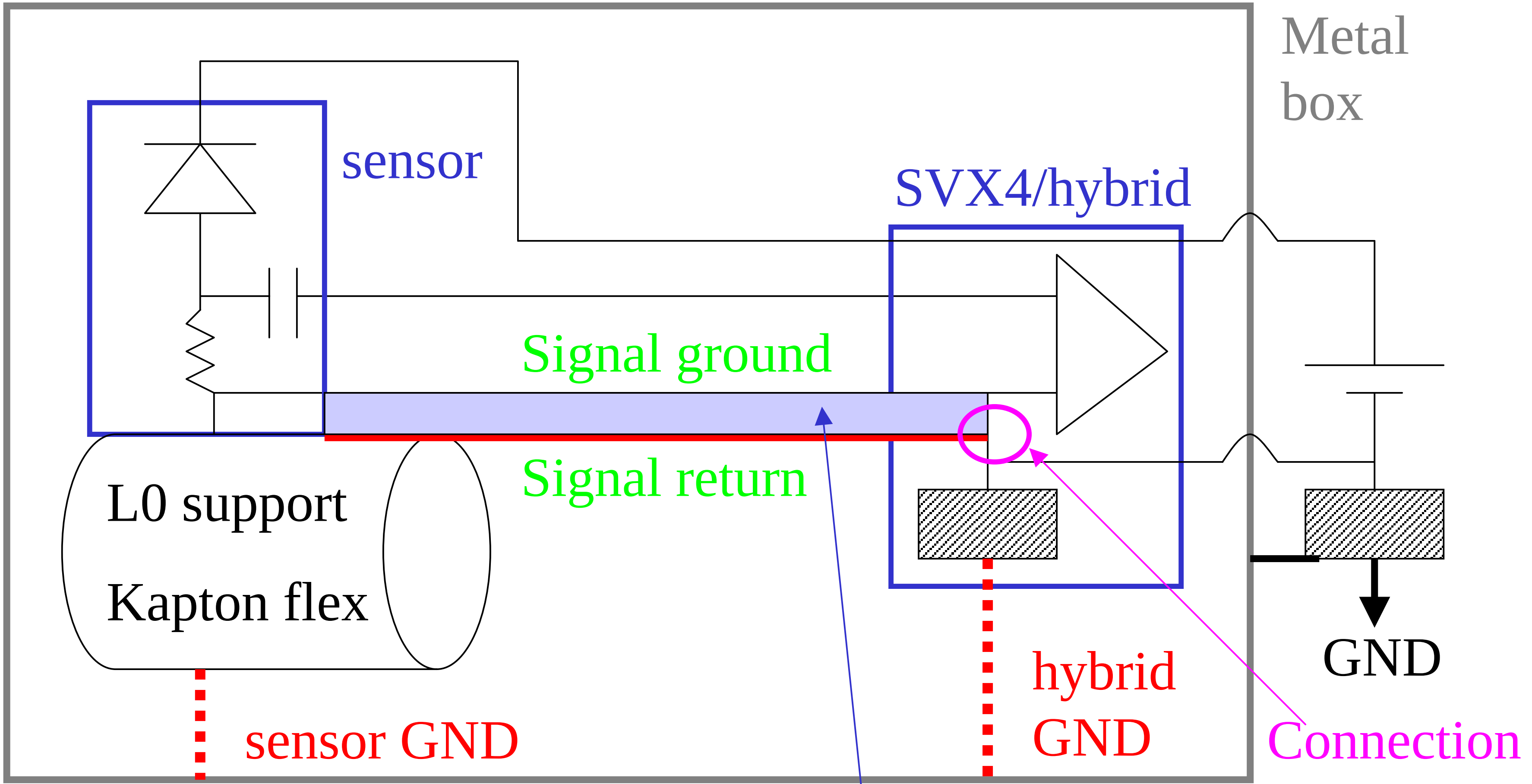


Effect of Grounding

Structure inside the aluminum box.



Equivalent (?) circuit (cont'd)

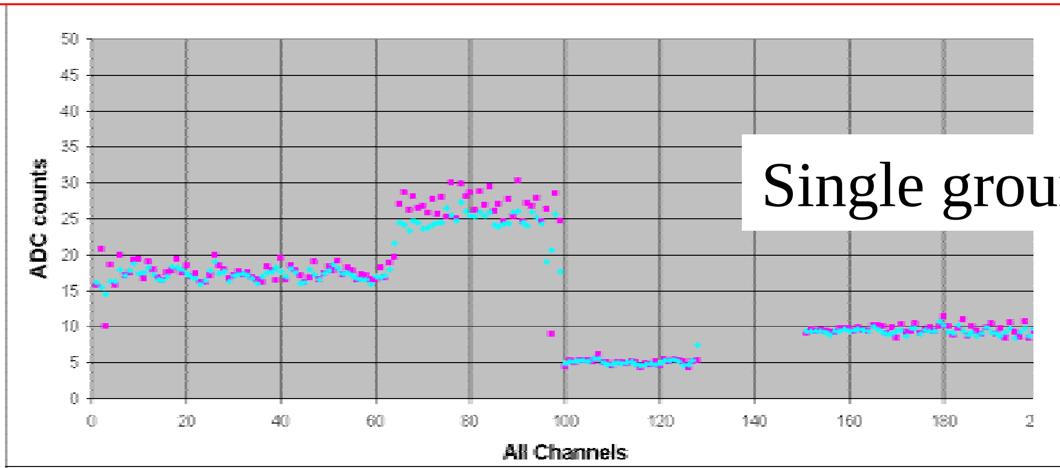


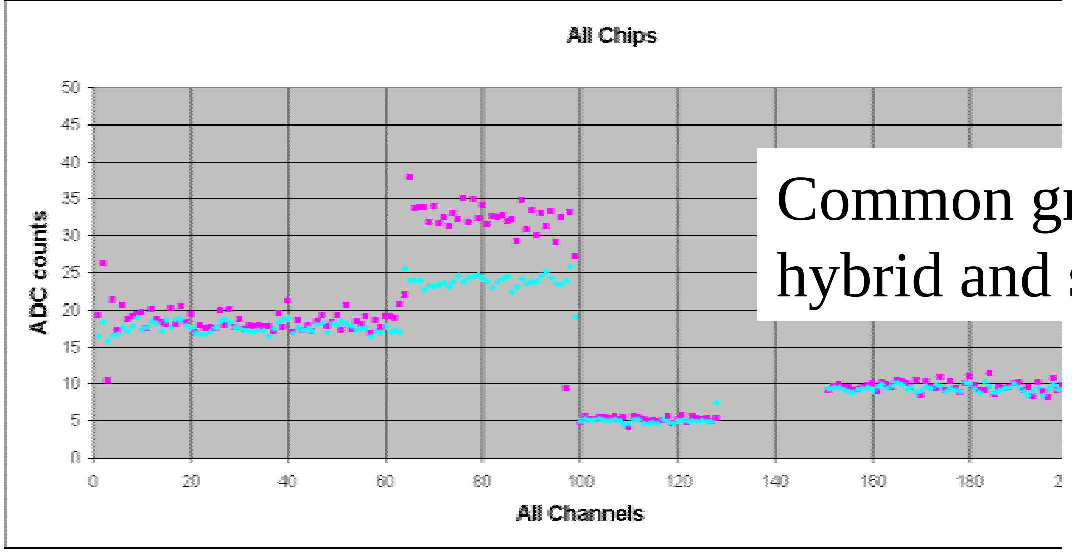
Smaller inductance (or smaller loop)

Least impedance = least inductance
for high frequency (not resistance).

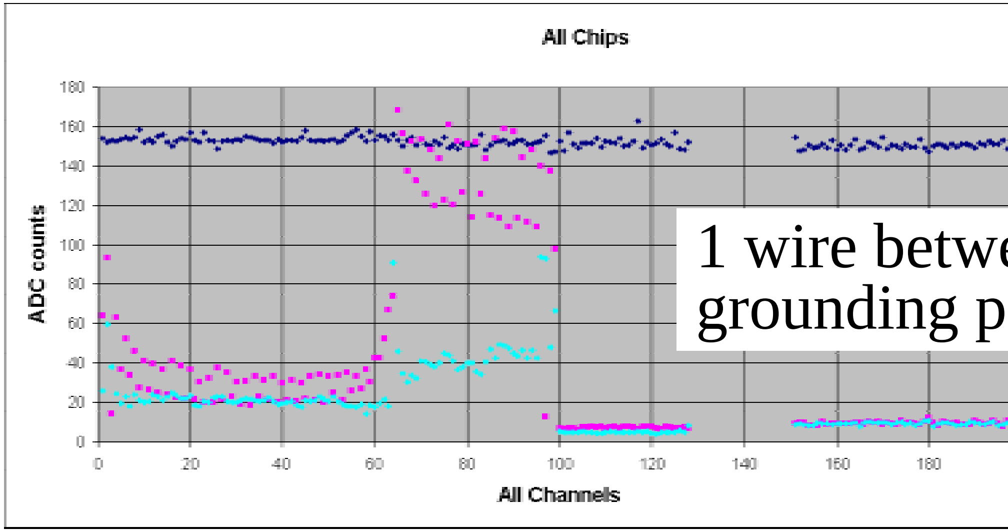
After putting extra grounding plane

Note! Still the hybrid grounding is not perfect in terms of getting low inductance… but the effect of the extra ground plane is clearly seen.



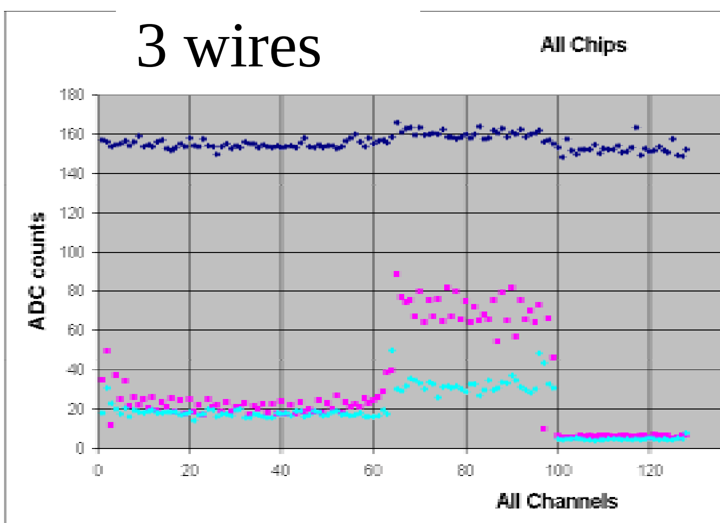


Importance of low inductance connection

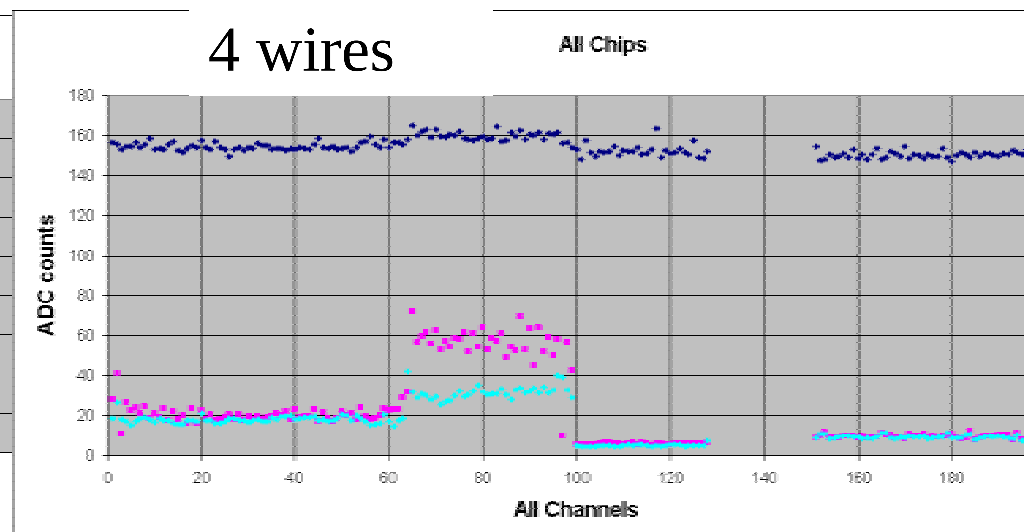


1 wire between hybrid and the extra grounding plane.

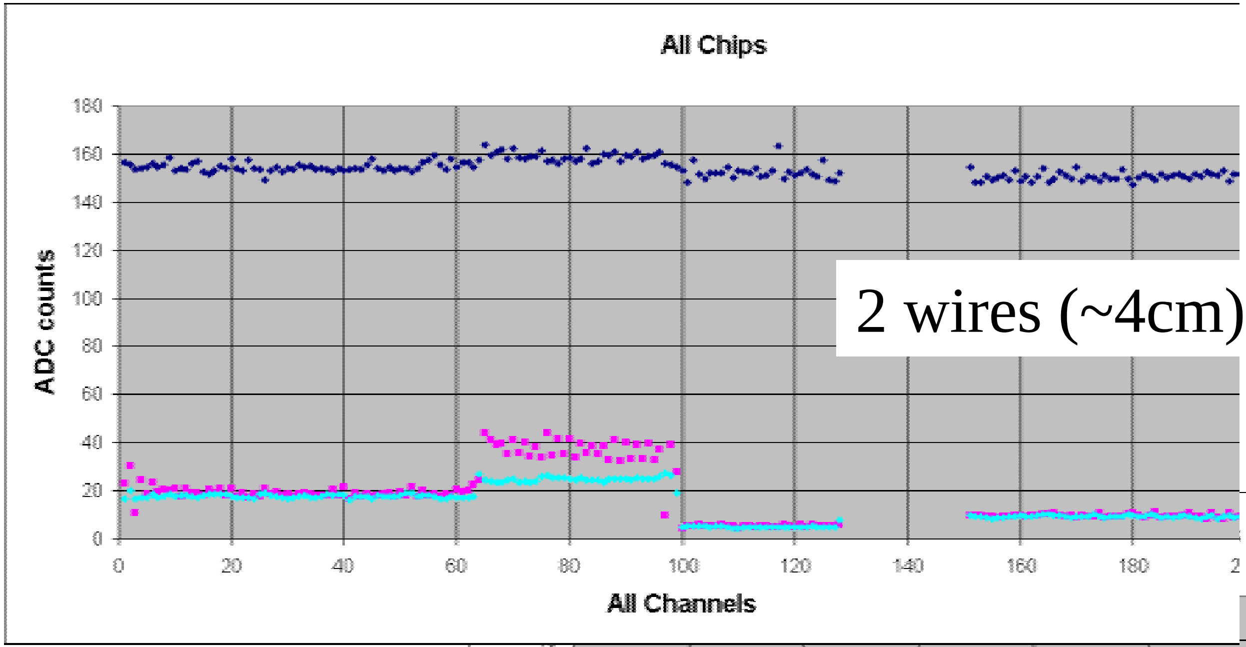
3 wires

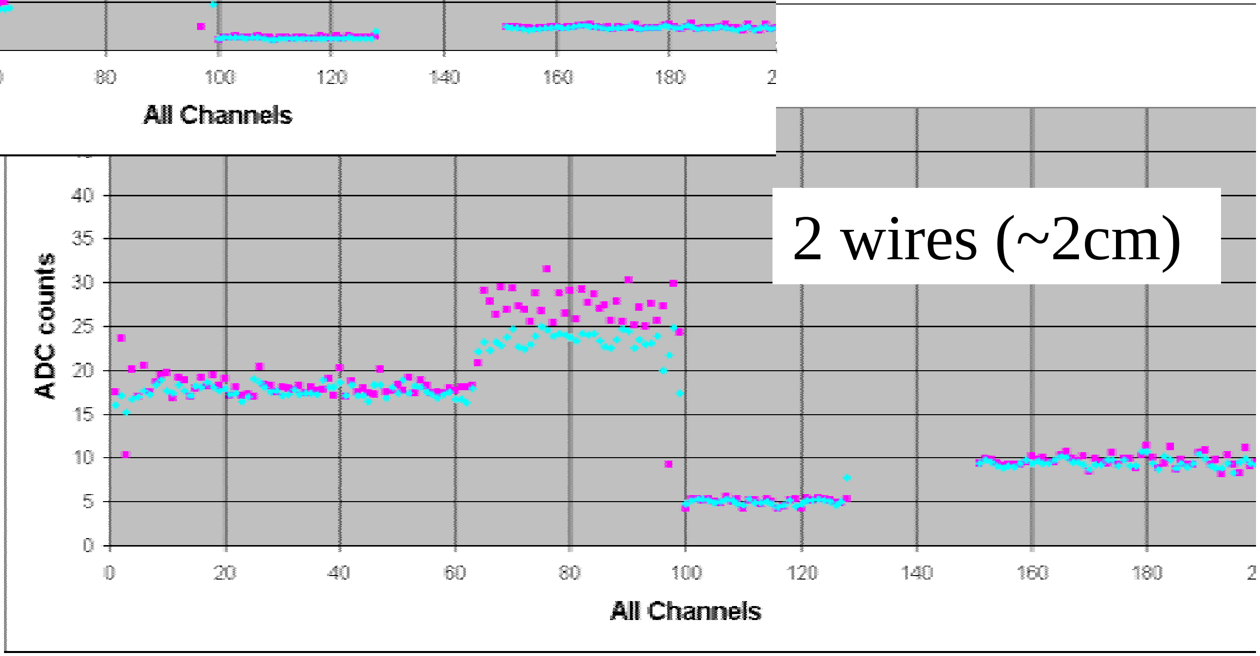


4 wires



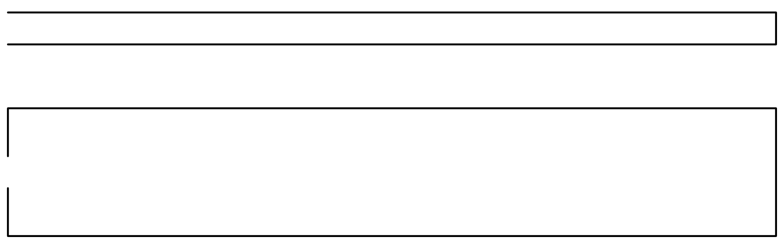
Low inductance connection (cont'd)





Reducing the inductance

- Having lower inductance connection to GND seems crucial.
- L ~ (wire) length/radius: $M=\mu l/2\pi[\log(2l/r)-1]$
- $L = \Psi/I$
- Ψ ~ area of the closed circuit

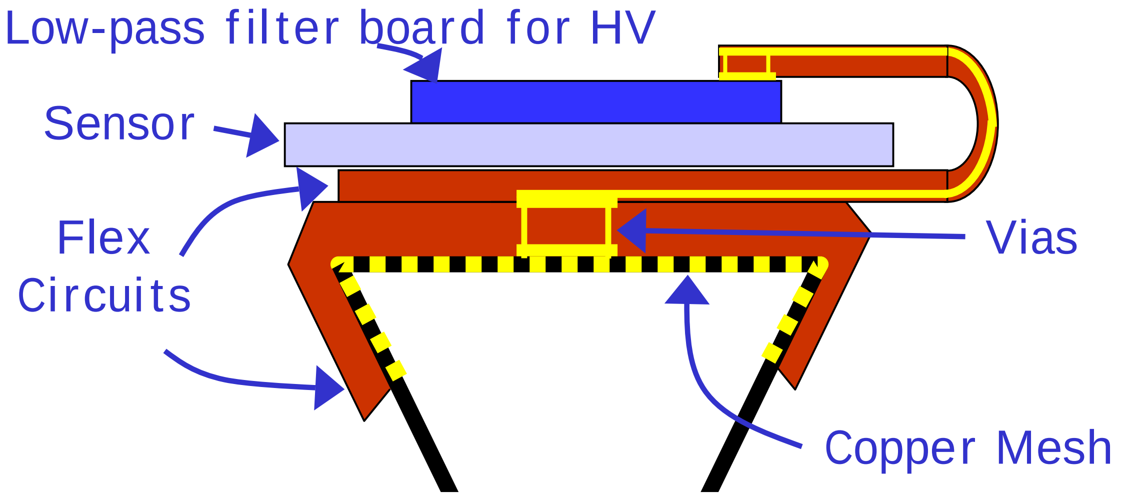


better

- People know these rules well, but sometimes forget to apply.
- But these rules are always critical for any grounding connections, both locally and generally.

How do we achieve????????????

- Sensor grounding.



- The sensor and hybrid need to be connected through rigid ground plane. This should work also as a shielding.
  ← extension of kapton flex with copper mesh embedded.
- Hybrid side: proposal using the similar technique, but not yet decided.
- Need to decide; multi point ground vs single point ground.

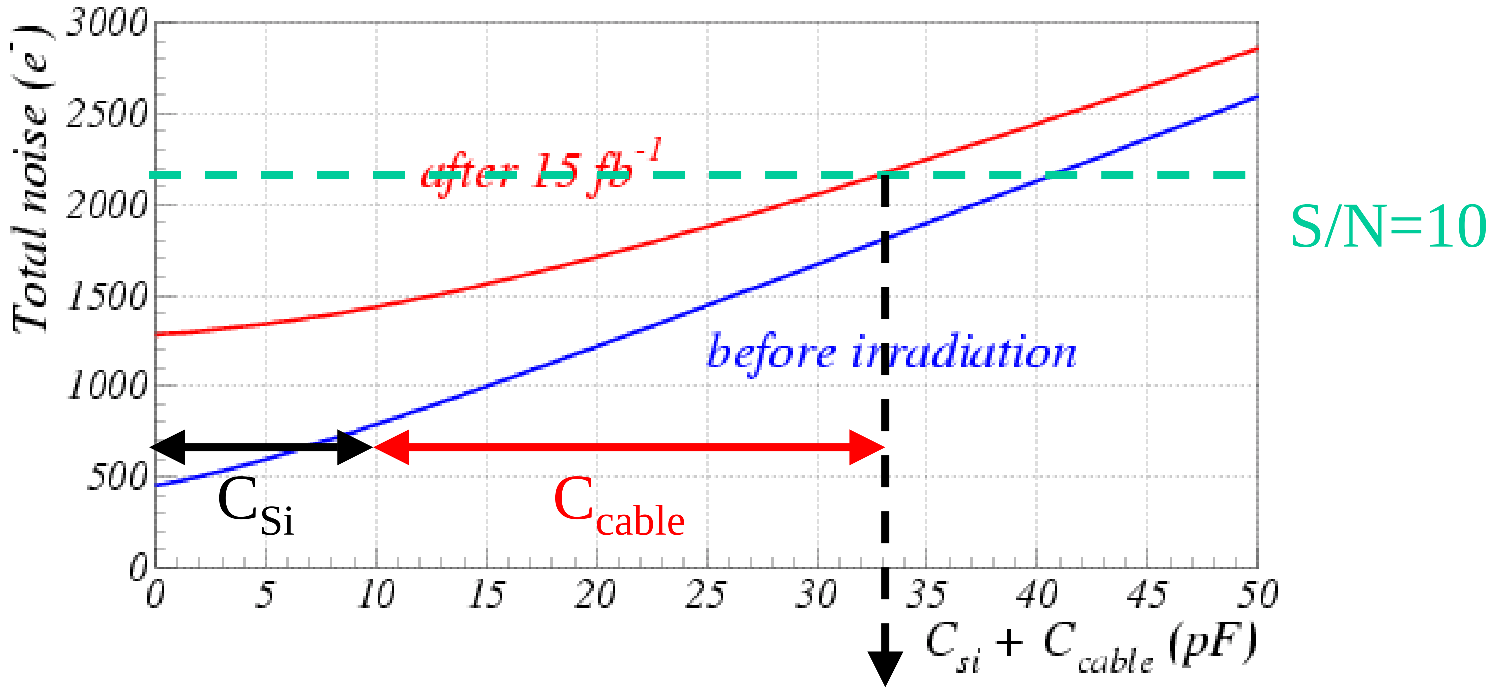
Summary

- The analog cable design almost fixed.
- Capacitance ~ 0.35pF/cm.
- Proximity of analog cable to grounding/shielding material has an impact on the noise performance. 🡐 may need lower dielectric spacer and/or distance.
- Analog cable is just a part of the solution to make a low noise detector. 🡐 The ground return is critically important.
- Connection of any shields to ground etc. is also important (low inductance).
- Any solution needs to be a system solution.

…Backup Slides

Cable design (noise due to capacitance load)

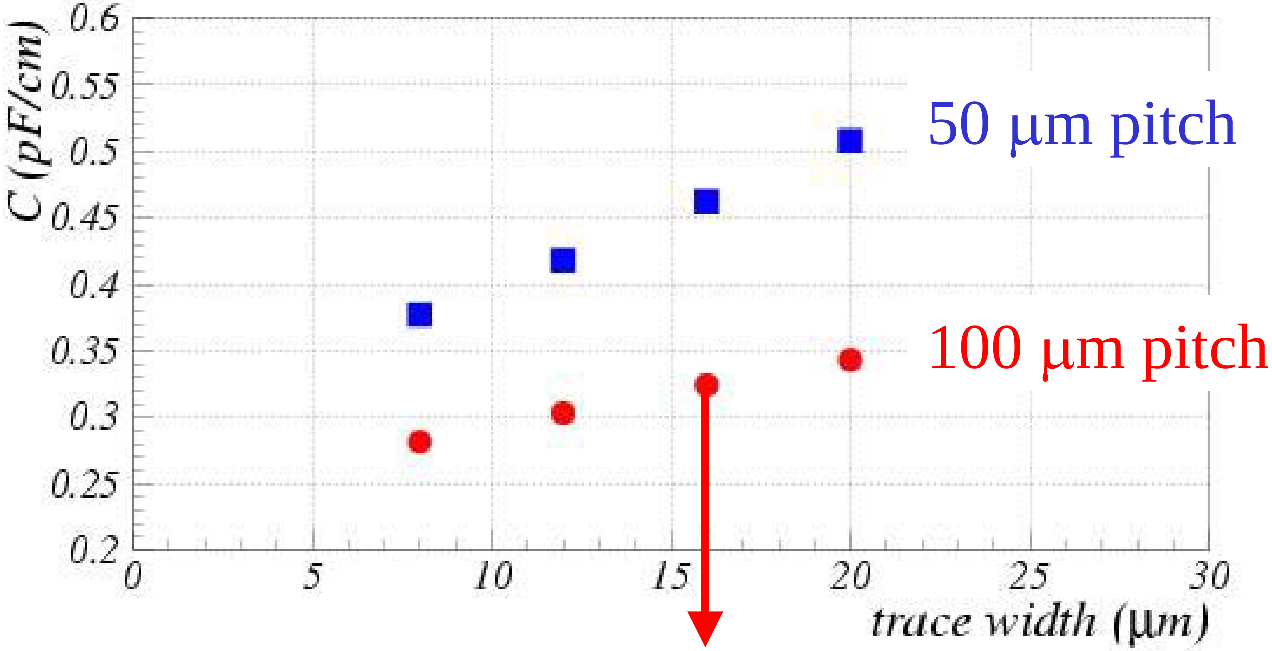
Total noise estimates VS total capacitance (C_{si} + C_{cable})



S/N=10 after 15fb^{-1} ➔ C_{cable} < 23pF for 43.5cm long cable

➔ C_{cable} < 0.53pF/cm

Cable design (capacitance calculations)



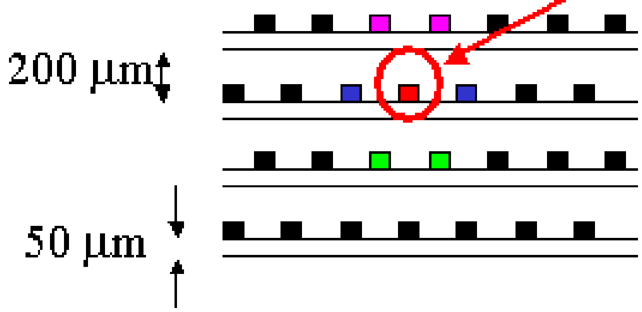
16 μm wide trace with ~100 μm pitch satisfies the requirement of <0.53pF/cm

- 50 μm thick Kapton substrate (ε_r = 3.5).
- Copper trace with 8 μm height.
  ➔ Calculation agrees with measurement with 10% for the 1st prototype.

Capacitance calculations

Trace pitch = 100 μm
Trace size = 8 x 16 μm

C = 0.328 pF/cm



contributions from:
two neighbors = 0.208 pF/cm
two top neighbors = 0.014 pF/cm
two bottom neighbors = 0.017 pF/cm

Dielectric constants: 3.5 for kapton substrate, 1.0 (air) for the space between the cables.

ε_r (spacer)	C(pF/cm)
1	0.328
2	0.449
3	0.566

kapton's ε_r fixed to 3.5

Radiation length

Min (2 cables)		Max (12 cables)	
100μm Kapton	0.04%	600μm Kapton	0.21%
3μm Cu (a)	0.02%	16μm Cu (a)	0.11%
300μm (b) polypropylene	0.07%	1300μm (b) polypropylene	0.32%
20μm Al (c)	0.02%	20μm Al (c)	0.02%
Total	0.15%	Total	0.66%

- (a) 16% of area occupancy is taken account.
- (b) 50% of volume occupancy assumed. May be possible to reduce.
- (c) heavy duty aluminum foil was measured to 20μm thick.

Metrology Results

- measured only two cables of S1-A type:
  - hole diameter: 1.52±0.02 mm OK!
  - hole-hole distances:
    - 413.67±0.05 mm -> OK?
    - 27.27 ± 0.02 mm -> OK?
  - full length: 463.718 mm and 463.644 mm (should be 463.650 mm)
  - trace width: 19 μm, RMS <0.5 μm
    - however 1^{st} and 129^{th} trace have thickness of ~28 μm. Effect understood by company
    - specified 15 μm, but could also live with 19 μm
  - pitch: 91.5 μm, RMS<0.6 μm
  - HV & GND trace width: 0.1 mm
  - pad size: 45 x 120 μm

Misc. info.

- Information to solder mask on HV and GND trace:
  - WPS 80 from Multiline International
  - Photo-imagable covercoat
  - dielectric constant: ~3.5 @ 1 MHz
  - dielectric strength: 3kV/mil
  - actual thickness ~10 μm
  - tested HV trace up to 500V @ 1-2 mA
- glue for lamination:
  - Pyralux LF adhesive sheets from Dupont
  - acrylic adhesive